Issued August 30, 1907.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF CHEMISTRY—BULLETIN No. 106.

H. W. WILEY, Chief of Bureau.

CASSAVA:

Its Content of Hydrocyanic Acid and Starch and Other Properties.

BY

CHARLES C. MOORE,

CHIEF, PLANT ANALYSIS LABORATORY,

In Collaboration with the Bureau of Plant Industry.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF CHEMISTRY,
Washington, D. C., December 29, 1906.

SIR: I have the honor to transmit herewith the results of the chemical work performed in connection with the study of the amount of hydrocyanic acid and starch present in cassava. This investigation was undertaken in collaboration with the Bureau of Plant Industry to determine, by the cultivation of different varieties of cassava, which of the varieties contained the largest quantities of hydrocyanic acid and starch, and what were the conditions governing the variation in these constituents, especially the hydrocyanic acid.

The botanical description of the different varieties of cassava has been supplied by the Bureau of Plant Industry, which imported and propagated the varieties studied at the substations of that Bureau at Miami, Fla., and Biloxi, Miss.

I recommend that this report be published as Bulletin No. 106 of the Bureau of Chemistry.

Respectfully,

H. W. WILEY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

CASSAVA:

ITS CONTENT OF HYDROCYANIC ACID AND STARCH, AND OTHER PROPERTIES.

HISTORICAL NOTE ON PREVIOUS INVESTIGATIONS.

The presence of hydrocyanic acid (commonly called prussic acid) in cassava, and the resultant danger in eating this root unless it has been especially prepared, have restricted its use in the countries where it is indigenous to that of a human food. For centuries it has been an important food among the South American Indians, who peel and cook all varieties. This preparation eliminates the hydrocyanic acid, making a nutritious human food, while the unpeeled raw product may produce fatal results. For this reason it is not utilized in feeding stock, though it is a most valuable forage product except for the possibility of its being poisonous. In this country it is considered primarily as a forage product; secondly, as a source of commercial starch, glucose, and alcohol, and, thirdly, possibly as a human food.

BITTER AND SWEET VARIETIES.

Owing to the variation in content of hydrocyanic acid, the cassava has been divided into sweet and bitter varieties—that is, varieties which do not contain enough prussic acid to be dangerous are called sweet and the others bitter. The chemical work that has been done previously is so limited that it is merely suggestive of the lines of research that should be pursued. A review of the literature of the subject shows that it is not definitely known that the same variety is at all times either sweet or bitter.

In 1877 the Government analyst for Trinidad (Francis) examined some varieties of cassava and reported that the average percentage of hydrocyanic acid in the sweet varieties was 0.016, and in the bitter 0.027. The subject was not again considered for some years, and only within the past five years has the work been carried further by investigations at the Government stations in Trinidad and Jamaica. A series of results was obtained on the Trinidad varieties by the Government analyst at that station (Carmody). He reports the mean percentage of hydrocyanic acid in the sweet varieties examined as 0.010 and in the bitter 0.022. These analyses were made by a modification of the method used by Francis, and the results obtained by the two

analysts are in general accord. It is usually held that sweet varieties contain only half as much prussic acid as those known to have been fatal, and also that there is no distinct dividing line between the two, but a gradual merging of one into the other.

Carmody suggests that the difference between the two varieties consists in the hydrocyanic acid being distributed throughout the bitter kind, whereas in the sweet variety it is principally found in the cortex. His results show, however, that peeled sweet varieties contain from 0.003 to 0.015 per cent of hydrocyanic acid and peeled bitter varieties from 0.014 to 0.042 per cent, with practically no difference between the two kinds in the composition of the cortex, from 0.014 to 0.042 per cent of hydrocyanic acid being found in the cortex of both.

In a series of results obtained by the Jamaica analyst on tubers grown in Colombia, the mean percentage of hydrocyanic acid in seventeen varieties is 0.001, the maximum being only 0.003. This is in marked contrast to the previously determined mean of the Trinidad sweet varieties, which was 0.016 according to Francis and 0.010 according to Carmody. From these results it is concluded that all Colombian varieties are practically sweet, and this view is supported by a note to the effect that in the interior of Colombia the people do not know of the existence of poisonous varieties.

The analyses of three bitter varieties made in Jamaica (Cousins) show from 0.036 to 0.077 per cent of total hydrocyanic acid. In a series of twenty-five varieties the same analyst finds from 0.010 to 0.077 per cent of this poison, and in a third series six bitter varieties are found to average 0.018 and six sweet varieties 0.001 per cent. It is to be noticed that these bitter varieties are but a trifle higher in hydrocyanic acid than the mean of 0.016 obtained by Francis for sweet varieties at Trinidad.

Upon another occasion the Trinidad station sent to Jamaica for cuttings of their best varieties of sweet cassava and an analysis made of the tubers by the Trinidad analyst (Ince) gave 0.001 per cent of hydrocyanic acid present. In the report from Trinidad the question is raised as to the possibility of sweet varieties degenerating into poisonous varieties and the opinion is stated that certain varieties unquestionably undergo this change, the hydrocyanic acid content being to some extent dependent upon environment. The same station notes that residents of Colombia who have imported bitter varieties from Jamaica find that they become sweet.

METHODS OF ANALYSIS.

In considering the results discussed in the preceding pages, and in view of recent investigations, it is of peculiar interest to review the methods employed for estimating hydrocyanic acid at the Trinidad and Jamaica stations.

The following method is a modification by Carmody of that used by Francis:

The fresh tuber is cut in thin slices and allowed to stand in an equal weight of water in a closed vessel overnight. The liquid is decanted and an aliquot portion distilled, the hydrocyanic acid in the distillate being titrated with a silver salt. The sliced tubers are repeatedly treated with portions of fresh water, as many as five determinations may be made, and the sum of the results is reckoned as the total hydrocyanic acid.

In the use of this method it was observed that the first extraction generally yielded but a small portion of the total amount of acid and, further, that the tubers continued as long as observed to give off hydrocyanic acid upon continued digestion with fresh water. In Jamaica[a] the Government analyst (Cousins) continued this work, and writes as follows on this point:

For seven days a nearly uniform production of hydrocyanic acid took place when the sliced tubers were placed in water. The water was poured off every day, the hydrocyanic acid estimated, and a fresh supply added. Finally hydrochloric acid was used and this eliminated nearly the whole of the hydrocyanic acid. We have now ascertained that the total hydrocyanic acid may be estimated by treating the cassava with hydrochloric acid and distilling with steam.

In a report published in the Bulletin of the Imperial Institute[b] in 1903 on the investigation of poisonous fodders and food grains, the following observations are made:

Lotus arabicus.— * * * It was ascertained that the toxicity was due to the production of prussic acid, when the plant was moistened with water, as the result of the interaction of a glucoside and an enzyme occurring together in its cells. The glucoside (*lotusin*) was obtained in a pure state and shown to be a derivative of a yellow coloring matter (*lotoflavin*), the latter, in addition to dextrose and prussic acid, being produced when lotusin is hydrolyzed, either by the action of the enzyme (*lotase*) present in the plant, or by boiling it with dilute mineral acids. * * * * * * The amount of prussic acid obtainable from *Lotus arabicus* is considerable and varies from 0.26 per cent in the case of young plants to 0.32 per cent in the case of those almost mature, when the yield of acid reaches the maximum.

The statement is further made in regard to cassava (*Manihot utillissima*, that "this plant also contains a cyanogenetic glucoside, which, in its decomposition, furnishes the prussic acid hitherto generally believed to exist free in the tuber."

From a Trinidad report[c] the following note is taken having reference to this work:

Several published analyses of the cassava root appear to show that prussic acid is obtainable by allowing the sliced material to rest in the presence of water for some hours, and that fresh amounts of poison can be extracted several times in succession. It is therefore possible that the primary poison content is largely added to by rapid

[a] Department of Agriculture, vol. 2, pts. 6 and 7.

[b] Vol. 1, pp. 13 and 15.

[c] Trinidad, Botanical Department, Bulletin of Miscellaneous Information, No. 41, January, 1904, p. 26.

decomposition, when the material is allowed to rest in the presence of water. As yet, however, we do not appear to be in possession of the exact amount of poison the roots originally contain, for in the laboratory processes the method has been to extract with water, causing a "cyanogenetic" process to be set up, which actually appears to generate the acid.

In the work of the Trinidad station (Carmody) it is noted that the analyst in experimenting upon both grated and sliced samples obtained after two hours' digestion only 0.003 per cent of hydrocyanic acid, and that upon continued extraction he gets a total of 0.012 per cent. He calls attention to the fact that the one extraction of but two hours made by Francis gives higher results than his nine extractions, and suggests that this may be due to the exceptionally dry season. From further observations on Carmody's work it appears that on some samples he obtained practically the total hydrocyanic acid on the first extraction.

From these comparisons it is apparent that some of the results obtained at these two stations may be correct and some may be erratic, depending upon whether the production of hydrocyanic acid had been completed at the time the estimations were made. From the reports of the Trinidad and Jamaica stations it is not possible to ascertain whether the two stations at any time worked on pedigreed varieties. This feature, in addition to the possible source of error just mentioned, renders it difficult to draw any conclusions from the work done.

EXPERIMENTAL WORK ON CASSAVA CONDUCTED BY THE DEPARTMENT OF AGRICULTURE.

INTRODUCTION.

The great value of cassava as a feeding stuff, could the possibility of disastrous results from poisoning be entirely eliminated, seems to justify an extended research on this point. Cassava may be grown in any of the Gulf States, and in the introduction of new varieties something definite should be known of their habits and characteristics before they are brought into general cultivation.

It can not be assumed that the observations recorded in this report will be verified another season, even at the same places. Only a series of similar experiments continued for a number of years can conclusively establish the points under consideration. Some of the varieties studied undoubtedly have properties which make them superior to others, such as yield, form, composition, and resistance to disease. Some preliminary experiments made it evident that certain varieties yield a better grade of meal than others, some being so woody that they can not be masticated by animals.

It is also desirable to ascertain the actual yields of the varieties under field culture, and to obtain definite data on the production of meal and its value for starch making and as a feeding stuff. While extensive experiments would be necessary to definitely establish con-

clusions on these various points, it is believed that the data given in the following pages are both of interest and of value in consideration of the state of the knowledge of the subject at present.

BOTANICAL DESCRIPTION OF VARIETIES OF CASSAVA STUDIED.[a]

No. 9670. Pacho.

Plants 3–3½ feet, widely branched; stalks short jointed, green with brown tinge; divisions of the leaf 7, petioles long, green with pink tinge; no seed; roots numerous, very long, slender, red, 8½ pounds.

No. 9671. Pacho.

Plants 4 feet, widely branched from the base; stalks rather smooth, long jointed, dull green below and light green above; leaf divisions 7, petioles green; no seed; roots white, numerous, long, tapering, 7 pounds.

No. 9672. Pacho.

Plants 4–5 feet, vigorous; stalks dull green, smooth; leaf divisions 7–9, narrow, petioles long, dark purple; no seeds; roots red, medium size, 4 pounds.

No. 9674. Helada.

Plants 4–5 feet, widely branched; stalks brownish green below and reddish above; leaf divisions 5–7, narrow, petioles red; seed abundant; roots few, light colored, tapering, 18–24 by 2–2½ inches, 4 pounds.

No. 9675. Helada.

Plants 4–5 feet, very vigorous, well branched; stalks smooth, greenish gray; leaf divisions 7, rather large, petioles bright red; seed abundant; roots pink, good shape, 12–18 by 2–2½ inches, 8½ pounds, keep well.

No. 9676. Helada.

Plants 4 feet, slender; stalks brownish below and purplish above; leaf divisions 5–7, very dark colored, petioles bright red; a few mature seed; roots pinkish yellow, good shape, 18–84 by 2–2½ inches, 9½ pounds.

No. 9677. Helada.

Plants 2–3 feet, weak; stalks short jointed, olive green; leaf divisions 5–7, petioles short, red; roots yellowish white, large, good shape, 18–24 by 1½–2 inches, 10½ pounds.

No. 9678. Helada.

Plants 4–5 feet, branching low; stalks light colored; leaf divisions 3–7, petioles bright red at base and apex, green in middle; seed abundant; roots pinkish yellow, poor shape, 24–36 by 1–1½ inches, 5 pounds.

No. 9679. Helada.

Plants 2–3 feet, weak; stalks green with purple tinge above; leaf divisions 3–7, mostly 5, petioles short, purple at base and apex, green in middle; seed few; roots yellowish pink, good shape, 24–48 by 2–2½ inches, 14 pounds.

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[a] Furnished by the Bureau of Plant Industry.

No. 9680. Helada.

Plants 4–5 feet, erect, not vigorous, branches few; stalks rather smooth, long jointed, greenish pink; leaf divisions 3–7, mostly 5, petioles short, red; no seed; roots red, good shape, 24–48 by 1½–2 inches, 8 pounds

No. 9681. Pie de Paloma.

Plants 5 feet, much branched, very vigorous stalks, grayish green below, purple above, short jointed; leaf divisions 7, petioles bright red; few seed; roots light pink, slender, tapering, 5 pounds.

No. 9682. Negrita.

Plants 3–4 feet, vigorous, widely branched; stalks rough, brownish green, short jointed; leaf divisions 7, petioles long, light green; seeds few; roots dark red, good shape, 18–30 by 1½–2 inches, 11 pounds, good keepers.

No. 9683. Negrita.

Plants 5 feet, very vigorous, widely branched from the base; stocks purplish green, smooth, long jointed; leaf divisions 1–7, mostly 3, very dark colored, petioles red; seed abundant; roots dark red, good shape, 24–48 by 2½–4 inches, 16 pounds. One of the best.

No. 9684. Negrita.

Plants 4–5 feet, vigorous, few branches; stocks olive green with purple tinge, long jointed; leaf divisions 3–7, mostly 5, petioles long, dark purple; seed abundant; roots dark red, good shape, 12–24 by 2 inches, 11 pounds.

No. 9685. Negrita.

Plants 4–5 feet, very vigorous, much branched; stalks brownish green below, light green above, long jointed; leaf divisions 5–7, narrow, petioles green and slightly pink at apex, seeds freely; roots dark red, good shape, 24–48 by 2–2½ inches, 10 pounds.

No. 9686. Negrita.

Plants 3–4 feet, branched high, stems greenish gray, short jointed; petioles medium in length, pinkish green with a bright red spot at base and darker toward the apex; leaf divisions 5–7, rather narrow; no flowers or seeds; roots light colored, good shape, 6 pounds.

No. 9687. Cajon Amarilla.

Plants 3–5 feet, irregular, widely branched; stalks brown below, dark green with purple tinge above, short jointed; leaves light colored, divisions 5–7, petioles long, pinkish yellow above, darker at base; seeds few; roots dark red, rough, fair shape, 7½ pounds.

No. 9688. Noto Seves.

Plants 4–5 feet, erect; stalks smooth, grayish green; leaves light green, divisions 7–9, narrow, petioles light yellow; seed immature; roots reddish yellow, poor shape, 12–48 by 1½–2 inches, 8½ pounds.

No. 9689. Cabesa Dura.

Plants 4 feet, vigorous; stalks brownish green, rough, short jointed; leaves light colored, divisions mostly 7, rather narrow, petioles long yellowish green; seed abundant; roots dark red, very brittle, poor shape, 12–36 by 1–1½ inches, 11 pounds.

No. 9690. Pie de Perdiz.

Plants 5–6 feet, vigorous, branches few and long; stalks brown below, green with purple tinge above; leaves light colored, divisions 7, petioles dark red at base, lighter above; seeds few; roots dark red, good shape, 24 by 2–2½ inches, 11 pounds.

No. 9691. Cenaguera.

Plants 5–6 feet, vigorous, widely branched; stalks dark green below and dark purple above; leaves dark colored, divisions 7, petioles dark purple; seed abundant; roots dark red, good shape, 18–30 by 1½–3 inches, 16 pounds. Heaviest root 22 pounds.

No. 9692. Chindi.

Plants 4 feet, weak, little branched; stalks brownish, long jointed; leaf divisions 5–9, petioles long, light yellow; no seed; roots reddish yellow, very slender, poor shape, 8 pounds.

No. 9693. Mantera.

Plants 3–5 feet, weak; stalks olive green below, light green above, rather smooth, long jointed; leaf divisions 7, petioles light green with pink tinge; no seed; roots light colored, very long, slender, tapering, poor shape, 8 pounds.

No. 9694. Lineva de Vendo. (Limonadi.)

Plants 4 feet, much branched, not thrifty; stalks olive green with purple eyes, short jointed; leaf divisions 5–7, petioles long, purple; seeds few; roots light colored, slender, tapering, 9 pounds.

No. 9695. Solida Amarilla.

Plants 3–4 feet, much branched; stalks light olive green; leaves light colored, divisions 5–7, petioles light colored; mature seed few; roots dark red, poor shape, 24–60 by 1½–2 inches, 12 pounds.

No. 9696. Mantera.

Plants 5 feet, erect, few branches; stalks red-brown, few branches, short jointed; leaf divisions 7, petioles dark purple; seed not matured; roots dark red, good shape, 24–36 by 2 inches, 12 pounds.

No. 9698. Solida Blanco.

Plants 3–4 feet, sickly, few branches; stalks dark green, short jointed; leaf divisions 7, rather narrow; few mature seed; roots dark red, slender, poor shape, 6 pounds.

Common Florida.

Plants 4 feet, well branched, compact; stalks olive green below, lighter with pink tinge above, short jointed; leaf divisions mostly 7, petioles dark red at base and apex, lighter in the middle; roots red, 18–30 by 1½–2 inches, 9½ pounds.

No. 15. Negrita.

Seed from Porto Rico, 1904. Plants strong, 4–5 feet; stalks greenish purple; leaf divisions 3–7, petioles purple; no mature seed; roots nearly white, good clusters, 12–36 by 2–2½ inches, 9 pounds.

No. 17. Negrita.

Seed from Porto Rico, 1904. Plants thrifty; stalks green; leaf divisions 7, petioles purple; seed few; roots very long, slender, dark red, 8 pounds.

METHODS OF ANALYSIS.

The method of analysis employed in these investigations was distinctly different from that of previous analysts working along these lines, though it was based upon the same general principle, namely, that hydrocyanic acid can be expelled by heat and made to combine with an alkali, when it forms a definite salt. In detail the method used for the estimation of the hydrocyanic acid was as follows:

Pulp the fresh tuber, a machine designed for grating horse-radish being used. Place 540 grams of this pulp in a retort without the addition of water and heat gently on an asbestos board over an open flame, continuing the digestion long enough to insure the complete expulsion of the acid—about two hours is usually necessary. (The retort used was a pear-shaped iron vessel covered with porcelain enamel and was about three-fourths full when containing the charge specified. This vessel was closed by a No. 10 rubber stopper carrying a quarter-inch glass tube which dipped into a solution containing sufficient potash to take up all the hydrocyanic acid expelled.)

The general method at this point is to titrate with a silver salt. There are, however, two sources of error involved in this procedure, one arising from the fact that a minimum excess of potassium in the resultant distillate can not be insured, as the amount of acid driven over is unknown and the accuracy of the titration varies with the excess of potassium hydrate present. A further error and one of much more importance is due to the fact that organic matter is driven over and so discolors the solution that the end reaction is obscured. For these reasons a modification of the method was introduced at this point.

Place the distillate in a flask, treat with an excess of sulphuric acid, and immediately stopper with a connecting glass tube which dips into water containing about 5 cc of tenth-normal potassium hydrate. Heat the flask gently to drive over the liberated hydrocyanic acid and titrate with tenth-normal silver nitrate as soon as the distillation begins. In solutions of this strength approximately 2 cc of potassium hydrate unite with the hydrocyanic acid and form potassium cyanid with the equivalent of 1 cc of the silver nitrate solution. With this procedure it is easy to provide for a minimum excess of potassium hydrate, as this can be added when the silver nitrate approaches equilibrium. Each cubic centimeter of the silver nitrate used is the equivalent of 1 part per hundred thousand of hydrocyanic acid on the basis of 540 grams of substance used. Duplicates obtained on samples taken from the same lot of well-mixed pulp were almost identical.

In the use of this method it was observed that the greater part of the hydrocyanic acid is expelled in the early stages of the operation

and that long-continued heating produces no variation in the results as compared with those given by the minimum time required to estimate the acid. From this fact and the nature of the results obtained there is no reason to believe that the figures given represent other than the hydrocyanic acid existing in a free state.

The accuracy of the method of analysis was further checked during the season of 1905 at the Miami station, by making the following determinations:

Hydrocyanic acid gas was liberated from potassium cyanid and absorbed in cold water, the amount of acid in this solution being definitely determined. Four samples of a variety of cassava which had been found to contain less than 0.001 per cent of hydrocyanic acid were selected for the experiment. The first sample was run as a blank, to the second 2 cc of the water solution of the hydrocyanic acid were added, 4 cc to the third, and 8 cc to the fourth. In a fifth retort, containing no cassava, 8 cc of the solution were placed. All of the determinations were made simultaneously and according to the usual method, and the results obtained showed a satisfactory agreement with the theoretical figures, except in the instance when 8 cc of the solution were added to the charge, when the determined result was 0.018 and the theoretical figure 0.021. This is probably due to the fact that the hydrocyanic acid solution was added by dropping it into a pocket made in the pulped material and, being rapidly volatilized, was not distributed throughout the charge, as would be the case when present naturally. The results obtained are shown in Table I. All of the retorts used were tested by adding a definite amount of hydrocyanic acid water and distilling it off, the results in all cases agreeing with those obtained by direct titration. This experiment was made to eliminate any error that might be due to the liberated acid combining with the metal of the retort.

TABLE I.—*Comparison of theoretical and actual determinations of hydrocyanic acid, Miami, 1905.*

[10 cc hydrocyanic acid water = 27 cc of tenth-normal silver nitrate.]

Cassava.	Hydrocyanic acid added.	Silver nitrate solution required.	Theoretical requirement.
Grams.	*cc*	*cc*	*cc*
540	0	0.5	0.0
540	2	4.4	5.4
540	4	10.2	10.8
540	8	18.1	21.6
000	8	21.4	21.6

The question was also considered as to the possibility of the hydrocyanic acid being present in combination with a base, and thus being nonvolatile. To determine this point, the juice of two plants was expressed and an aliquot portion of each sample was distilled and the

hydrocyanic acid collected and estimated in the usual way. A corresponding portion of the juice was treated with sulphuric acid, which would have liberated the hydrocyanic acid from any base with which it could have been combined. This mixture was also distilled and the acid titrated, the similar results obtained on the treated and untreated juice, as shown in the following table, indicating that no hydrocyanic acid was present in a nonvolatile form:

TABLE II.—*Determinations of hydrocyanic acid on samples prepared with and without sulphuric acid.*

Sample number.	Amount and preparation of solution.	Silver nitrate required.
	cc	*cc*
1	200	3.3
1	200+H_2SO_4	2.9
2	200	3.3
2	200+H_2SO_4	3.3

The effect of fermentation on the content of hydrocyanic acid was also tested by grinding 2 kilos of cassava and keeping it in a moist condition. The fresh sample showed a content of 0.003 per cent of hydrocyanic acid, when four days old 0.002 per cent was found, and the sample was decomposed on the sixth day.

A cassava meal made from a sweet variety was tested, 540 grams being treated with water and distilled, and only a trace of hydrocyanic acid was found.

PEDIGREED VARIETIES OF CASSAVA GROWN AT BILOXI, MISS.

SEASON OF 1904.

At this station thirty-nine pedigreed varieties were grown in the year 1904 by the Bureau of Plant Industry of this Department. Twelve of these were direct importations from Porto Rico and the remainder were taken from the subtropical station at Miami, Fla., where they were propagated the preceding year, at which time they had been secured from the Jamaica station. During the month of November, the time of harvesting the tubers in Biloxi, the hydrocyanic-acid content was studied, the determinations being made upon the freshly harvested cassava at Biloxi, according to the methods of analysis previously described.

The primary object of the study was to identify the sweet and the bitter varieties and to ascertain their water and starch content. In addition to the pedigreed plants a common Florida variety was grown, which was taken from the stock in general cultivation in that State. The results obtained on these tubers are given in Table III.

TABLE III.—*Analysis of pedigreed varieties grown at Biloxi, 1904.*

Serial number.	Variety.	Weight of roots.	Moisture.	Starch in dry sample.	Hydrocyanic acid.	
					Sample I.	Sample II.
		Kilos.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	Porto Rico Rodney	3.3	71	40	0.009	0.003
8	Porto Rico White Top	4.7	50	55	.030	.028
9	Porto Rico Mars Jack	3.6	61	60	.009	.009
11	Porto Rico Auntie Grace	2.5	59	53	.028	.022
12	Porto Rico Negrita	3.8	55	67	.006	.006
13	Porto Rico St. John	2.6	58	52	.008	.007
15	Porto Rico Negrita	....	53	54	.009	....
15[a]	Porto Rico Negrita	1.3	58	55	....	....
16	Porto Rico Coriana	3.0	60	48	.010	.009
17	Porto Rico Negrita	2.4	61	69	.015	....
18	Porto Rico Porto Lona	3.7	62	64	.008	.008
77	Porto Rico Unknown	5.0	53	65	....	....
9670	Pacho	3.8	64	78	.010	....
9671	Pacho	3.2	58	82	.008	.009
9672	Pacho	1.9	61	79	.008	....
9674	Helada	1.9	61	78	.011	.014
9675	Helada	2.7	62	77	.019	.018
9676	Helada	2.4	59	79	.008	.008
9677	Helada	2.9	59	82	.019	.008
9678	Helada	1.5	57	79	.010	.010
9679	Helada	2.3	69	78	.022	.022
9680	Helada	3.2	65	76	.012	.010
9681	Pie de Paloma	2.4	67	53	.010	.013
9682	Negrita	2.0	59	79	.010	.008
9683	Negrita	2.4	60	73	.010	.004
9684	Negrita	2.7	60	64	.005	.005
9685	Negrita	2.6	60	75	.018	.013
9686	Negrita	3.6	60	75	.008	....
9687	Cajon Amarilla	2.5	55	52	....	....
9688	Noto Seves	3.3	60	76	.012	....
9689	Cabesa Dura	2.4	57	76	.010	.016
9690	Pie de Perdiz	4.1	60	66	.002	.005
9691	Cenaguera	5.3	59	58	.003	.003
9692	Chindi	2.7	61	78	.012	.011
9693	Mantera	3.3	58	78	.009	.007
9694	Lineva de Vendo (Limonadi)	3.8	61	76	.008	....
9695	Solida Amarilla	2.4	58	77	.005	.002
9696	Mantera	2.6	62	78	.026	.023
9698	Solida Blanco	2.4	60	72	.011	.009
....	Common Florida	....	....	....	.002	.002

[a] Third year from Porto Rico.

The common Florida variety, known as Florida Sweet, contains about 0.002 per cent of hydrocyanic acid, while the most common bitter variety, known as White Top, contains 0.030 per cent. It happens that in the series of determinations reported in Table III there is a progressive gradation between these extremes, although there is no marked line of distinction between the two classes. Furthermore, some of the varieties supposed to be bitter contain no more hydrocyanic acid than some of those designated as sweet, and in those that are unclassified there is a range from 0.003 to 0.026 per cent. Therefore in selecting varieties for cultivation for forage product it becomes necessary to establish a line of safety.

It is of course a difficult matter to establish the minimum fatal dose of a poison, especially in the case of one as active as hydrocyanic acid. In a work on toxicology by Peterson the history of many fatal doses of hydrocyanic acid is given. One instance cited is that of a woman 22 years of age who took the equivalent of 0.04 gram of hydrocyanic acid and died in fifteen minutes. A man who took the same

dose was unconscious for four hours and then recovered. It is probable that 0.04 gram closely approximates the minimum fatal dose, and that even half as much would produce ill effects. Therefore if an adult should eat as much as 130 grams of the extreme bitter variety, containing 0.03 per cent of hydrocyanic acid, fatal results might be expected.

There are no definite data obtainable regarding the minimum fatal dose in the case of animals, numerous cases of death from eating cassava being recorded, but without any statement as to the amount of prussic acid in the tubers or the quantity eaten. However, a fair approximation may be made by a comparison with the effects produced on human beings. The toxicity of poisons will be assumed to be somewhat in proportion to the weight of the animal, and as a steer is about ten times the weight of a man, it may be assumed that in the eating of 1 kilo of the White Top variety fatal results might be produced. Five kilos of such foodstuff would probably be a short ration for a steer, as it contains about 60 per cent of moisture. On this basis it is estimated that such a ration, made up from a variety containing as much as 0.008 per cent of hydrocyanic acid, would prove fatal to a steer. Of the forty plants examined thirty-two would be classed as dangerous in accordance with these deductions.

In the examination of these plants some results were obtained which are thoroughly in accord with the common usage of the natives in the preparation of the plant. A fine specimen of the bitter White Top was selected (No. 8), the total root of the plant weighing nearly 5 kilos, which is unusually large. The tuber was divided into three parts, (1) the thin dry outer covering or bark, which is black and constitutes about 1 per cent of the sample; (2) the cortical layer free of bark, a pink peel about one-sixteenth of an inch thick and constituting about 25 per cent of the sample, and (3) the peeled tuber. The bark has but little moisture, and the hydrocyanic acid in it is calculated to a dry basis, amounting in the sample under consideration to 0.068 per cent of hydrocyanic acid. The peel, calculated on the fresh basis in which it existed, contained 0.054 per cent, while the peeled tuber contained only 0.002 per cent. That is to say, a peeled root of the extreme bitter variety contained no more hydrocyanic acid than the whole root of an extreme sweet variety. A tuber from the same plant free of bark contained 0.020 per cent of the acid.

A root of the Florida Sweet, weighing approximately 3 kilos, was examined according to the same scheme and the bark was found to contain about 0.076 per cent, the peel (12.5 per cent of the sample) 0.023, and the peeled tuber only a trace, i. e., 0.0005 per cent. These figures immediately suggest that the smaller the root the higher the relative content of hydrocyanic acid, as the percentage of peel is higher in a small root. This deduction was confirmed by an actual

estimation. A good sized, tapering root of the bitter White Top variety was selected for examination, one sample comprising the portion from the tip up to a diameter of 1 inch and the other the remainder or large part of the tuber. The sample representing the large end of the root contained 0.028 per cent of prussic acid and the small end contained 0.039 per cent. This point was further confirmed by the examination of a small root, less than 1 inch in diameter, of the Florida Sweet variety, which contained 0.005 per cent, while the average plant of that kind contains only 0.002 per cent. It is seen that uniformity in hydrocyanic acid content does not exist even in the same variety, it being proportionate to the size of the root. The same conditions obtain in different roots of the same plant.

In making the analyses of the plants reported in Table III the entire root system was ground and mixed previous to taking the sample. From the figures just given it is seen that in order to make these results comparable the size of the roots must be considered. An approximate idea of the size can be obtained from the figures for weight given in the table, the total weight of the roots of each plant being given. For example, the extremely bitter White Top (No. 8) weighed nearly 5 kilos and contained 0.03 per cent of hydrocyanic acid, while another bitter variety, the Auntie Grace, contained 0.028 per cent, practically the same as the White Top, but weighed only 2.5 kilos. Had the Auntie Grace been as large as the White Top root it might have been classed as a semibitter.

In this group of thirty-nine foreign varieties but two approach the Florida Sweet in low content of hydrocyanic acid, these being Nos. 9690 and 9691 in the table. These were very large plants, weighing 4.1 and 5.3 kilos, respectively, while the Florida-grown plants of the same weight would probably contain not more than 0.001 per cent.

With the exception of the hydrocyanic acid content there is no marked difference between the roots of the sweet and the bitter varieties. The White Top has an unusually large and well-shaped root, being similar to the Florida Sweet in shape and equally palatable. As shown in the table, it contains 55 per cent of starch, calculated to dry substance. In an examination made by the Bureau of Chemistry of a large number of plants of the Florida Sweet variety grown for the manufacture of starch the starch content ranged from 50 to 75 per cent of the dry substance. In the starch percentages given in Table III there is about the same range. There appears to be no relation between the starch and the hydrocyanic acid content.

Season of 1905.

In the second year of the investigations at Biloxi the work was devoted primarily to the development of seedlings, which phase of the investigations was conducted by the Bureau of Plant Industry. It

was impracticable to take up the chemical study when the crop was at the height of its maturity, the analyses not being made until the last of December, which is far past the season for cassava in that section.

The known extreme bitter varieties of the previous year had been eliminated in the seedlings produced, but owing to the loss of all the canes of that year's crop through rotting during the winter a new set of canes, of the same varieties, was obtained from the Miami station. This new importation of canes and the seed from the previous Bilòxi crop were planted together at the latter station for the second year. This change, combined with the delay in making the chemical study, the roots being already in an advanced stage of deterioration, makes the results hardly comparable with those of the previous year, and, as would be expected, they do not accord, and add little to the knowledge of the effect of environment upon the hydrocyanic-acid content of the crop. The analyses, made according to the same methods as in the previous year and by the same analyst, are tabulated in Table IV.

TABLE IV.—*Hydrocyanic-acid content of cassava grown at Biloxi, 1905.*

Serial number.[a]	Hydrocyanic acid.	Serial number.[a]	Hydrocyanic acid.	Serial number.[a]	Hydrocyanic acid.
	Per cent.		*Per cent.*		*Per cent.*
9674	0.002	9679	0.004	9684-3	0.003
1	.004	9680	.001	9685	.003
2	.004	9681	.001	A	.003
3	.005	1	.004	9686	.003
4	.002	3	.006	9687	.002
5	.002	4	.001	2	.006
B	.005	5	.018	9688	.001
S	.002	6	.005	9689	.002
T	.007	S	.004	9690	.002
9675	.002	9682	.007	9691	.003
1	.003	9683	.002	1	.002
9676	.003	1	.003	2	.003
1	.009	2	.003	3	.003
2	.003	3	.002	4	.004
3	.004	4	.002	A	.001
4	.005	A	.003	B	.003
A	.004	S	.004	9693	.001
B	.003	9684	.001	9694	.001
9677	.002	1	.004	9695	.003
9678-1	.002	2	.003	9696	.002
2	.009				

[a] The supplemental numbers and letters in connection with the original pedigree numbers indicate the seedlings from that strain, the letters representing a later planting.

The entire series given in Table IV is below the semibitter standard with the one exception of a very small plant, which perhaps had a maximum cortical layer for the content of starch.

In the eight seedlings obtained from the original plant No. 9674 only one, with a content of 0.007 per cent, approached the amount of hydrocyanic acid in the parent plant, which contained 0.011 per cent in 1904 (see Table III, page 15). One seedling from No. 9676 exceeded the parent plant in hydrocyanic-acid content; one from No. 9678 practically equaled the parent plant of 1904, and one from No. 9681 doubled the hydrocyanic-acid content of the parent plant and became bitter. The remainder of the seedlings did not exceed the parent plants in the per-

centage of this constituent present. All of the new cuttings from Miami proved to be lower in hydrocyanic acid than the same numbers grown in Biloxi the previous year. Were it not for the fact that the two sets of analyses were not made at the same time of year, the results would seem to substantiate the theory that all varieties grown in Florida in time cease to be poisonous.

PEDIGREED VARIETIES OF CASSAVA GROWN AT MIAMI, FLA., AND VICINITY.

Season of 1904.

HYDROCYANIC ACID.

In the latter part of January, 1905, the examination of samples of cassava grown at Miami, Fla., was begun. Twenty-eight varieties imported direct from Jamaica were grown, twenty-seven of which were classed as sweet, and one, No. 9699, known as a poison variety, died before a complete study could be made of it. The plants had been growing for fifteen months at the time the analyses were made, the same apparatus and methods being used as at the Biloxi station and the work done by the same analyst. The results, compared with those obtained at the Biloxi station, are given in Table V.

Table V.—*Comparison of analyses of same varieties of cassava grown at Biloxi, Miss., and at Miami, Fla., 1904.*

Serial number.	Hydrocyanic acid.			Starch (calculated to dry substance).		Moisture.	
	Biloxi, Miss.	Miami, Fla.[a]		Biloxi, Miss.	Miami, Fla.	Biloxi, Miss.	Miami, Fla.
		Minimum.	Maximum.				
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
9670	0.010	0.003	....	78	65	64	67
9671	.008	.001	....	82	63	58	69
9672	.008	.001	....	79	64	61	72
9674	.011	.001	0.006	78	60	61	74
9675	.019	.002	.003	77	54	62	73
9676	.008	.0005	....	79	63	59	67
9677	.019	.001	....	81	66	59	60
9678	.010	.001	.011	79	63	57	66
9679	.022	.002	.014	78	73	69	68
9680	.012	.001	.008	76	69	65	66
9681	.010	.001	.013	53	67	67	70
9682	.010	.0005	.011	79	75	59	62
9683	.010	.001	.014	73	73	60	62
9684	.005	.002	.006	65	69	60	63
9685	.018	.0005	.010	75	63	70	67
9686	.008	.001	.016	77	65	59	70
9687	.018	.003	.008	52	66	55	60
9688	.012	.002	.008	76	66	60	61
9689	.010	.002	.006	76	69	57	54
9690	.002	.002	.016	66	73	60	66
9691	.003	.004	.010	59	81	59	60
9692	.012	.005	.009	77	62	77	62
9693	.009	.002	.012	78	64	78	66
9694	.008	.003	.011	76	63	75	66
9695	.005	.003	.014	77	75	77	55
9696	.026	.002	.010	78	72	78	67
9698	.011	.001	.009	....	....	....	....

[a] Some samples from Lemon City and Dania also.

In the twenty-eight so-called sweet varieties the hydrocyanic acid ranged from 0.0005 to 0.016 per cent, and more than half of them contained 0.002 per cent or less. Referring to the Biloxi results on the corresponding numbers, it will be seen that two-thirds of the samples contained 0.010 per cent or more, and No. 9696, almost the extreme bitter variety at Biloxi, would be classed as sweet at Miami. Variety No. 9699, grown at Miami, which had been brought over as a poisonous type, contained only 0.018 per cent of hydrocyanic acid, whereas in its native country the same variety, though not from pedigreed cuttings, had shown more than 0.05 per cent of the poison. (See Table VI.)

A series of the same pedigreed cuttings had been planted at Dania and another series at Lemon City, respectively 20 miles and 5 miles north of Miami. The soil at Dania was black humus known as "glade land," and the plantings were practically a failure. However, samples, though very small, were taken of all varieties that produced tubers, and these, as a series, were found to be similar in hydrocyanic-acid content to the cassava produced at Miami, varying from 0.0005 to 0.011 per cent. By referring to Table VI it will be seen that certain corresponding numbers varied. No. 9685, which contained 0.0005 per cent of prussic acid in Miami, contained 0.010 when grown at Dania, and No. 9691, which contained 0.007 at Miami, showed only 0.0005 at Dania.

Most of the varieties planted at Lemon City lived and made good yields, the soil at this point being of the same sandy nature as that in Miami. In general the series grown at Lemon City shows the same content of hydrocyanic acid as that grown at Miami, and in the majority of cases approximately the same results were obtained on corresponding numbers at the two stations.

At Lemon City the plants, being a year old, were just beginning to put on a spring growth, and it was planned to make a series of analyses which would represent weekly periods of growth to determine whether periodic changes occurred in the hydrocyanic-acid content. The plants were sampled daily and the estimations made in duplicate, the figures obtained being recorded in Table VI.

TABLE VI.—*Percentages of hydrocyanic acid in the same variety of cassava grown in different localities and in the same variety analyzed on different dates.*

Serial number.	Miami.	Dania.	Lemon City.				Miami and Lemon City.		Lemon City.	Miami and Lemon City.	Miami.
9670	Jan. 21 to Feb. 21. 0.003										
9671	.001		Feb. 13–18. 0.001								
9672	.001							Miami, Mar. 25. 0.003			
9673	.002										
9674	.004		.001					.006			
9675	.002		.002	Mar. 2. 0.003							
9676	.0005										
9677	.001										
9678	.001		.0005	.001	Mar. 10. 0.007	Mar. 17. 0.014			Mar. 29. 0.011		
9679	.002		.002	.002	.010	.013	Miami, Mar. 21–23. 0.014	Mar. 27. .010	.008	Miami, Mar. 29. 0.005	
9680	.001		.0005	Mar. 3. .001	.008	Mar. 20. .006	.005			.001	
9681	.001	Feb. 1–5. 0.001	.001	.003	Mar. 11. .013	.010	.007		.007		
9682	.0005		.006	.003	.011	.011	.011		.009	.002	
9683	.001	.001	.004	Mar. 4. .006	.014		.003		.013	.001	
9684	.002	.011	.005			Mar. 14. .006	.006		.005	.004	
9685	.0005	.010	.001	.009	Mar. 13. .010		.009			Mar. 30. .004	
9686	.002	.001	.007	.016	.014		.007	Lemon City, Mar. 24. .006	Mar. 30. .005	.008	
9687	.008	.001	.008			.004	.005	.003	.006	.004	
9688	.004		.002	Mar. 7. .005	.008		.008	Mar. 25. .002	.006		
9689	.005		.006	.006		.006	.006	.002	.005		Mar. 31. 0.003
9690	.005		.005	.009		Mar. 15. .008	.006	.002	.016		.004

TABLE VI.—*Percentages of hydrocyanic acid in the same variety of cassava grown in different localities and in the same variety analyzed on different dates*—Continued.

Serial number.	Miami.	Dania.	Lemon City.				Miami and Lemon City.		Lemon City.	Miami and Lemon City.	Miami.
9691	Jan. 21 to Feb. 21. 0.007	Feb. 1-5. 0.0005	Feb. 13-18. 0.004			Mar. 15.	Miami, Mar. 21-23. 0.006		Mar. 30. 0.010		Mar. 31. 0.006
9692	.005	.002	.008	Mar. 8. 0.009		0.010	.006	Mar. 27. 0.006		Lemon City, Mar. 31. 0.006	
9693	.002		.002	.006		.012	.009			.007	
9694	.003	.002					.010				.011
9695	.010	.001	.003	.014		Mar. 16. .014	Lemon City, Mar. 23. .011	.011		.008	.012
9696	.006	.0005	.004	Mar. 9. .002		.010	.006			.010	
9697	.001									Miami, Mar. 30. .009	
9698			.003	.002		.007	.009				
9699[a]	.018	Miami, Feb. 23. .004									
Common Florida		Dania, Feb. 5.				.005	.004	.003			
Common Florida		.004									
Common Florida		.003									
Common Florida		Coconut Hill.[b] .001									

[a] A poison variety.

[b] Coconut Hill is 23 miles north of Miami.

The results on the Lemon City cassava show that the content of hydrocyanic acid in some varieties remained practically constant, while others show a marked increase. Until March 17 it was thought an average increase was taking place, although there were many fluctuations. On March 21–23, a second series of analyses was made on the Miami tubers, and at intervals thereafter, the same being interspersed among the data for Lemon City.

From a general study of Table VI, it will be seen that the content of hydrocyanic acid appears to reach a maximum about the middle of March, and at this time the Miami results closely duplicate those obtained for the corresponding numbers at Lemon City. Toward the close of March the content of the acid seemed to decrease, though specific cases can be found which show a definite increase, or a constant amount of the poison present. In studying these fluctuations, it must be borne in mind that no plant was analyzed a second time, and it is possible that the change is not so great as appears between two given periods, inasmuch as an individual plant which shows an increase over another one at a successive period might have shown the same difference had the two plants been examined on the same day. In other words, the variation may be in part individual and not due to the periodic change.

The one known poison variety, No. 9699, was found to contain 0.018 per cent of prussic acid on the first analysis and only 0.004 when examined a month later. As there were only two of these plants, the series could not be further extended. A common Florida variety, nonpedigreed, from a field near Lemon City, was studied from March 16, practically no fluctuation in hydrocyanic acid being observed during the ten days of observation, the content of acid being low at all times.

The results in Table VI suggest that the content of hydrocyanic acid may undergo a variety of changes during the growth of the plant, and may even disappear entirely at times and again be present. If the maximum and minimum results on the same varieties grown at Miami and Lemon City be compared with the results on the same varieties grown at Biloxi (see Tables V and VI), it will be seen that at some period each variety grown at Miami and Lemon City was practically free from hydrocyanic acid. Further, it will be noted that during a second selected period more than half of each variety reached the maximum limit for sweet varieties, and some numbers which were distinctively sweet at Biloxi were semibitter when grown at the Florida stations, while others that were semibitter in Florida were dangerously so in Biloxi. None of the Florida-grown varieties becomes more than semibitter, while in Biloxi two-thirds of the samples are semibitter and about one-fourth are considerably more than half bitter.

It is generally believed that the common stock of cassava known as the Florida Sweet is always sweet, and also that any variety brought into Florida will eventually become sweet. None of the common Florida varieties examined has shown more than a small quantity of hydrocyanic acid, and it appears therefore that the popular belief is well founded. The general results of the work indicate that the environment in Florida is such as to retard the chemical-physiological action which produces the hydrocyanic acid. It may be shown later that continued cultivation under such conditions will change the nature of the plant in this respect.

STARCH AND MOISTURE.

The starch percentages given in Table V for Miami and Biloxi samples are not strictly comparable, as those from the latter station were determined on selected portions of the tuber, while the analyses of the Miami roots were made on samples taken from the total pulped tubers representing the plant or plants. The Miami samples therefore would include much more of the cortical layer and small ends, and would yield a lower percentage of starch than a selected portion. The Miami samples represent more accurately the actual yields. In Table VII is given the starch content of the Miami tubers in 1904, in connection with the weight of the roots and the water.

The weight as shown in the table is the weight of a cluster, not a hill, the roots being grown in this way at the propagating station. A cluster may comprise two or three hills that have united, or it may include one hill from which tubers had been taken. The entire lot of tubers indicated by the weight were pulped and sampled for making the determinations reported.

TABLE VII.—*Water and starch content of Miami tubers, 1904.*

Serial number.	Weight.[a]	Moisture.	Starch.		Serial number.	Weight.[a]	Moisture.	Starch.	
			Moist.	Water-free.				Moist.	Water-free.
	Kilos.	*Per ct.*	*Per ct.*	*Per ct.*		*Kilos.*	*Per ct.*	*Per ct.*	*Per ct.*
9670	3.4	67	21	65	9687	2.9	60	26	66
9671	.7	69	20	63	9688	9.8	61	26	66
9672	1.9	72	18	64	9689	2.9	64	25	69
9673	1.7	69	21	67	9690	7.7	66	25	73
9674	2.6	74	16	60	9691	5.2	60	32	81
9675	2.7	73	15	54	9692	2.6	62	23	62
9676	2.9	67	21	63	9693	4.0	66	22	64
9677	3.2	60	26	66	9694	3.4	66	21	63
9678	2.8	66	21	62	9695	5.0	59	31	75
9679	12.0	68	23	73	9696	3.3	67	23	72
9680	7.0	66	23	69	9697	4.0	64	21	60
9681	3.4	70	20	67	9698	4.0			
9682	3.8	62	28	75	Common Florida		51	24	50
9683	3.3	62	28	73	Common Florida		60	20	51
9684	2.7	63	26	69					
9685	3.8	67	21	63					
9686	1.4	70	19	65					

[a] Weight of the ground tubers from which the sample was taken.

In considering cassava as a source of starch the moisture is an important factor, as the higher the water content the greater the tonnage,

without increased value. In the Florida samples reported the moisture ranged from 51 per cent in a common Florida variety grown in the field to 74 per cent in an imported sweet variety (No. 9674) grown in a nursery. This represents a difference between these two samples in dead weight equivalent to one-fourth of the tonnage. Evidently in the selection of varieties an effort should be made to reduce the moisture to a minimum.

SIZE AND FORM OF TUBERS.

In connection with the starch and moisture determinations a study was made of the size and form of the tubers, the results of which are shown in Table VIII. The tubers are divided into six classes according to form, i. e., cylindrical, partly taper, taper, oval, club, and dumb-bell shaped, and the tubers of each cluster were classified accordingly as accurately as possible, though no sharp dividing line can be drawn.

The classification was made with the idea that some relation might exist between the shape of the tuber and its starch and hydrocyanic-acid content. Apparently, however, no such relation exists, though the nursery propagation to which the Miami plants were subjected may have modified their growth, the plants being through necessity grown in clusters and somewhat crowded as compared with plants grown in hills as in field culture.

The form of the tuber is a factor in plant selection second only in importance to the content of hydrocyanic acid. It was shown in the study made at Biloxi that the hydrocyanic acid was found principally in the cortical layer or peel, the relative amount of which is dependent upon the form of the tuber. Further, the ease with which the roots are pulled in harvesting is largely dependent upon their shape.

From a study of these plants, and many others, it appears that the most desirable forms of tubers are the cylindrical and the oval. The "partly taper" roots probably are formed when a cylindrical tuber is insufficiently nourished and shrinks at the end, while the taper form occurs when the root was not well nourished from the beginning and in consequence suffered a regular shrinkage. The dumb-bell form may be caused by an oval tuber taking on a second growth and then maturing, while the club form represents a second growth that did not mature.

In making up Table VIII the tubers of the greatest diameter and length were placed in column 1, which therefore represents the best tubers of the series. It will be noted that No. 1 occurs as club-shaped thirteen times, more than double the number of times that it appears as any other form. It is possible that the natural selection has been from tubers of the oval class. The latter form is better adapted to harvesting and handling and contains the minimum percentage of surface or cortical layer, which indicates an increase in starch and a decrease in hydrocyanic acid.

TABLE VIII.—*Size and form of Miami tubers (1904) pulped for sampling.*

[The figure outside the parenthesis is the length; the first figure inside the parenthesis is the greatest diameter, and the second figure the diameter 1 inch from the small end. All measurements are expressed in inches.]

Serial No.	Number and dimensions of roots.							Form of roots.					
	No. 1.	No. 2	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	Cylindrical.	Partly taper.	Taper.	Oval.	Club.	Dumb bell.
								Root No.	*Root No.*	*Root No.*	*Root No.*	*Root No.*	*Root No.*
9670	8 (3-1.2)	12 (21.2-1)	14 (2.5-2)	15 (1.7-.7)	7 (1.7-.7)	4 (1-.7)	5 (1-.5)	6, 7	1, 2, 3, 5			4	
9671	10 (1.15-1)	4 (1.5-1.5)	5 (1.2-15)	6 (1-1)	5 (1-.5)	6 (1-.2)		4	3		2	1, 6	5
9672	15 (2.5-1)	12 (2-.5)	10 (2-.5)	8 (1.5-.5	4 (1-1)	4 (1-1)	8 (1-.5)	5, 6	2	3, 4, 7		1	
9673	32 (5-.7)	14 (2-1.5)						2				1	
9674	11 (2.5-1)	16 (2-1)	25 (2-.5)	15 (1.7-1)					1	3, 4			2
9675	18 (3-1)	6 (2.5-1)	10 (2-.5)	19 (1.7-.5)	9 (1.5-.5)	18 (1.2-.5)	12 (.7-.7)	7	2, 5	1, 6		3, 4	
9676	8 (4.5)	9 (3.5)	10 (2-.7)							3	1, 2		
9677	13 (3-1)	13 (2.5-1.5)	11 (2.5-1.5)	6 (2.5-.7)	17 (2.2-1)	8 (2-1)			5		4	1, 3, 6	2
9678	12 (3.5-2.5)	22 (2.7-1.7)								1, 2			
9679	18 (3.5-1.5)	15 (3.5-3.5)	14 (3.5-3.5)	7 (3)	6 (3.5)	20 (3-1)	28 (2.5-1.5)	2, 3	6	7, 9	4, 5	1	
9680	18 (4-1)	16 (3-1)	4 (2.5-2)	11 (2.5-1)	10 (2.5-1)	17 (2.5-7)	10 (2.5-.5)		4, 5	2, 6, 7	3	1	
9681	22 (3-1)	10 (2.5-1)	6 (2-2)	4 (2-2)	10 (2-.5)	5 (1.5-1.5)	14 (1-.5)	3, 4, 6, 7	1, 2			5	
9682	15 (2.5-1)	12 (2.5-1)	16 (1.7-1.5)	22 (1.7-1.5)	7 (2.5-1)	4 (1.7)	6 (1.2-1.2)	7, 8	5	1, 3, 4	6	2	
9683	10 (4-2)	11 (2.5-1)	9 (2.5-1)	4 (2-1)	7 (2-.5)	5 (1.5-1)	5 (1.5-1.5)	4	1	2, 3, 5, 6, 7			
9684	16 (3-1)	11 (3-1)	12 (2-1)	18 (1.5-.7)	7 (1.5-.7)	6 (1.5-.7)			1, 2, 3, 4	5, 6			
9685	24 (4-1)	10 (2.5-2)	11 (2.5-.7)					2				1, 3	
9686	8 (2-2)	8 (1.7-.7)	13 (1.7-.5)	7 (1.2-1.2)	10 (1.2-1.2)	7 (1-1)		1, 4, 6		3			2, 5
9687	16 (2.5-.5)	11 (2.5-.5	20 (2-.7)	4 (2.5)	13 (2-.5)	9 (1.7-.1)	15 (1.5-1.2)			5	4	1, 2	3, 6, 7
9688	26 (5-1.2)	18 (4-2.5)	12 (3.7-1)	9 (3.7-2)	9 (3.5-1.5)	18 (2-1.2)			2, 6			4, 5	1, 3
9689	19 (2.2-1)	9 (1.7-.7)							2			1	
9690	20 (5-1)	30 (3.5-.5)	6 (3)	19 (2.2-.5)	12 (2-.5)	12 (1.7-5)				5, 6	3	1, 2	4
9691	7 (4)	11 (3.5-1.7)	10 (3.5-1.7)	10 (3.5-1)	5 (3)	8 (2.5-1)	4 (2.5)		4, 6		1, 2, 3, 5, 7		
9692	12 (2.7-1.7)	16 (2.5-.7)	12 (2.2-1.2)	4 (2.5)	3 (2)			3	1	2	4, 5		
9693	25 (4-1.5)	12 (3-1.2)	7 (2.5-2)						2, 3	1			
9694	25 (3.2-.5)	13 (2.7-1)	19 (2.2-.2)	5 (2-2)				4	2			1, 3	
9695	7 (3-2)	10 (3-1.5)	10 (3-1.5)	13 (3-1)	15 (3-.7)	16 (2.5-.7)	9 (2-1)	1	2, 3, 4	6, 7		5	
9696	27 (3.5-.7)	4 (3.5)	12 (3-1)	9 (2.5-2.5)				4			2	1	3
9697	17 (3-2)	16 (2.7-1)	5 (2-2)	13 (2-1.7)	7 (1.5-.7)			1, 3	2, 4, 5				
9698	16 (3.2-2)	22 (2.2-.2)	16 (2.2-1)	10 (1.7-.5)	5 (1.5-1.5)	7 (1.5-.7)	9 (1.2-.7)	5	2, 3, 4	6		1, 7	

SEASON OF 1905.

In the spring of 1905 a crop of cassava was grown on new ground in Miami from the same pedigreed varieties raised in the previous year, and a chemical study was made of the crop in January of 1906.

As the purpose in view was to establish a vigorous strain by obtaining a two years' growth of the same root, only one series of observations was made, the results of which are given in Table IX. The figures for hydrocyanic acid are below the semibitter standard, though in the majority of cases they are higher than those obtained for the same variety in the previous year, and when tabulated with the results for the same year at Biloxi, the opposite condition is found—i. e., the Miami tubers are higher in hydrocyanic acid than those grown at Biloxi. It would appear, therefore, that the hydrocyanic acid content of these plants is beyond question a variable factor, even in the same varieties grown under the same climatic conditions.

In connection with these figures there are given in Table IX some results obtained on the same pedigreed numbers grown in Cuba. These analyses were made by the analyst at the Cuban central agricultural station and are published with his permission. The method of analysis of the Trinidad station was used, namely, that of inciting cyanogenetic action and determining the amount of hydrocyanic acid produced. This method of procedure is based on the hypothesis that a similar effect is produced during digestion, and therefore one should determine the amount of hydrocyanic acid which will be formed and liberated after the tuber is taken into the stomach, and not the amount present in a free state. An obvious fallacy in this argument is brought out in the evidence relating to cases of cassava poisoning, there being authentic cases in which death ensued in fifteen minutes after eating. The hypothesis, therefore, is untenable unless the acid is formed much more rapidly in the stomach than in artificial digestion, in which from several days to two weeks are necessary to complete the process, though in fact it continues until decomposition begins.

TABLE IX.—*Comparison of percentages of hydrocyanic acid found in the same varieties of cassava grown at Miami, Fla., Biloxi, Miss., and in Cuba, 1905.*

Serial number.	Miami, Fla.	Biloxi, Miss.	Cuba.	Serial number.	Miami, Fla.	Biloxi, Miss.	Cuba.
9671	0.002			9685	0.002	0.003	0.022
9672	.001			9686	.007	.003	
9673	.003			9687	.005	.002	.012
9674	.011	0.002		9688	.002	.001	
9675	.003	.002		9689	.005	.002	
9676	.010	.003	0.015	9690	.009	.001	.008
9677	.007	.002		9691	.002	.003	
9678	.009			9694	.002	.001	
9679	.003	.004		9695	.011	.003	
9680	.001	.001	.016	9696	.008	.002	.040
9681	.007	.001		9698	.005		.016
9682	.005	.007	.007	9699	.002		.013
9683	.002	.002					

PRESERVATION OF CASSAVA FOR MANUFACTURING PURPOSES.

For the manufacture of starch from cassava[a] the fresh tubers are delivered to the starch factory, and as they deteriorate rapidly after being harvested it is necessary that they should be grown in the vicinity of the mill. Thus the marketing of the crop is dependent upon the location of the mills as well as the demand for starch, with the exception of the small amount that may be grown for home consumption. For this reason it is desirable that some practical treatment of the tubers be developed which will eliminate the necessity for immediate utilization after harvesting. Experiments were conducted to demonstrate the feasibility of desiccating the ground tubers in small quantities and yet with commercial profit. It is, of course, perfectly practicable to prepare cassava meal, as has been done, if a suitable form of drying kiln be available, but to erect such a kiln would require too great an outlay for a farmer producing cassava on a small scale. The experiments were conducted, therefore, with a view to sun-drying with a minimum expenditure for equipment.

A 2-horsepower gas engine was used for grinding, the mill consisting of a revolving drum covered with a sheet of roofing tin punctured to make a grating surface. Over this a hopper was arranged, the whole resting on a suitable frame. This mill cost when complete, with shaft, boxings, and pulley, $10, and would grind 1 ton of tubers in one and one-half hours. Drying trays were made, consisting of a framework 2½ by 5 feet with a canvas bottom, at a cost of 25 cents each. As the trays were filled they were pushed out over a suitable runway, after which the ground cassava was occasionally stirred with a hoe or other tool.

The actual cost of preparation as determined by the experiment was $2.25 a ton, after the laborer thoroughly understood the work, his pay being $1.25 per day. At the time of the experiment the weather was exceptionally unfavorable, being cloudy and threatening. Only in one instance was it possible to grind roots and get the product dry enough to bag it in the same day. When the drying was not completed at the close of the day the trays were stacked under shelter to be put out again the next morning. When dried under the most favorable conditions, a fine white meal was obtained, but if the drying was prolonged the meal was discolored. When used for stock feeding, this discoloration is not objectionable. The greatest shrinkage in weight which occurred was 60 per cent, the meal then containing 8 per cent of moisture, and the average reduction in weight was 50 per cent.

Meal prepared in this manner and kept for eight months has shown no signs of deterioration, which means that the product can be stored

[a] U. S. Dept. Agr., Bureau of Chemistry, Bul. No. 58, The manufacture of starch from potatoes and cassava, 1900.

and marketed to much better advantage, and that the cost of transportation, which is one of the principal factors in the profitable production of this crop, has been reduced one-half.

MARKETS FOR CASSAVA MEAL.

Cassava meal can be marketed at a starch mill, and its preparation by the farmer in that form would render one step in the milling unnecessary, namely, the grinding. If the meal is white, it would undoubtedly bring a good price in this market.

An inquiry as to the use of starch in the textile industries brought out the possibility of supplying this crude meal directly to such concerns for use in making the lower grade of sizing mixtures. The meal as prepared on the farm can be ground and bolted in any flour mill and the flour thus prepared used in the making of gums, pastes, etc. Material prepared in this way was given a practical test by a firm which makes large quantities of such pastes, and was classed with low-grade tapioca starch, which sells at this time for about 1¾ cents a pound.

A further commercial use for cassava meal would be for the manufacture of industrial alcohol. If the meal is to be prepared expressly for this purpose, no special care is necessary in the drying, as the discoloration resulting from continued drying would in no way affect its value. Any grade that could not demand a good price for starch manufacture would be suitable for alcohol production.

Thus several distinct markets are already open for the sale of cassava in the form of meal, whereas the fresh tubers are practically sold only for starch making.

The use of the meal as a stock food has not been sufficiently investigated to warrant any authoritative statement on the subject. The possibility of the meal prepared for cattle food becoming poisonous through the cyanogenetic process was studied in the following manner: Five hundred and forty grams of dry meal were treated with water until it assumed approximately its original consistency. This mass was distilled according to the usual method for estimating hydrocyanic acid and only a trace was found. On this point attention is called to the following observation:[a]

> Cassava meal had been prepared from two varieties, "sweet" and "bitter." The samples were kept in sealed jars. When opened the "sweet" appeared to be good, but the "bitter" was strong with the odor of hydrocyanic acid. Upon analysis it was found to contain about 75 per cent of the amount found in raw and unprepared "bitter" tubers.

This work has not been repeated owing to the absence of "bitter" tubers. It is, however, contrary to the supposition that hydrocyanic acid is in a readily volatile form, in which case it would disappear in the preparation of the meal. Then the method of estimation, while

[a] St. Hill, Proceedings Agricultural Society, Trinidad, 1894.

not given, was probably the same as that in general use at Trinidad and Jamaica, and a "cyanogenetic" process may have been induced by it.

Cassava meal has long been used as a human food. The method of preparation used by the South American natives is to pulp the tuber, express the juice, and make the product into thin cakes, which are then cooked and stored. The properly prepared cassava has a distinctly nutty flavor, is palatable and nutritious, and is in general use in the West Indies.

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